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CHALLENGES IN MUSCULOSKELETAL MODELING FOR CLINICAL USE

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INTRODUCTION

Musculoskeletal modeling has evolved in the past five years from a field of scientific experiments to a tool applicable to solution of practical ergonomic problems. This paper very briefly points out a number of challenges the scientists and developers within this field must face in the forthcoming years in order to make the technology applicable also to clinical use.

Much of the scientific discussion concerning musculoskeletal modeling has been focused on the basic approaches and their divisions into forward and inverse dynamics with the former capturing the complexity of activation dynamics and the latter enabling models of realistic complexity. Recently, experiments with hybrid models have been reported (see, for instance, [1]), and with the development of computational technology, it must be foreseen that reliable analysis methods will be available in the future. This leaves the scientific community with the challenge of providing models with the necessary reliability, versatility and documentation for clinical applications.

CLINICAL REQUIREMENTS OF MUSCULOSKELETAL MODELING

It is useful to attempt a categorization of the requirements for clinical use of musculoskeletal models.

Morphological complexity: Since clinical applications are diverse, models with an adequate complexity to cover a wide range of cases must be available. One of the challenges here is that it is necessary to divide many anatomical muscles into several separate mechanical units [2]. We estimate that a full body model will comprise some 1000 independent muscle units.

Physical complexity: Muscles have nonlinear elastic properties, they wrap over and slide on bones and other muscles, and their contraction is due to a complex electro-chemical process. Joints are rarely ideal hinges, and many of the reaction forces in the body are unilateral and hence form contact mechanics problems. These are some of the physical complexities that must be addressed.

Individualization: Many clinical applications require models to be individualized. This is in particular the case for modeling of physical disabilities or prospective surgical procedures. A musculoskeletal model comprises thousands of parameters, so a full individualization made operational in a clinical setting is a challenging requirement.

Reliability and validation: Clinical models are used to make decisions on diagnostics, treatment, and rehabilitation of patients, and hence they must be reliable and validated. Errors can come from many sources including input, the musculoskeletal model, and the software used to process it. Further-



Figure 1: Musculoskeletal model of a box lift comprising roughly 500 muscles [4].

more forward dynamics models assume that the body moves optimal according to some criteria. Are these criteria still valid for patients? Proper validation must treat all these elements and do so as separately as possible from each other.

RESULTS AND STATE-OF-THE-ART

Due to space limitation, we shall focus on the issues of morphological and physical complexity. Anderson et al [3] demonstrated that a gait pattern can be reproduced in a model with reasonable morphological complexity in a forward dynamics model capturing the physical complexity of activation dynamics. Unfortunately, the computation times are prohibitive for clinical applications so far.

The AnyBody Research Group has announced an initiative [4] for assembling a public domain repository of musculoskeletal models written in the AnyScript body modeling language (Figure 1). The idea behind this initiative is that a public domain library will allow many scientists to contribute and scrutinize models, while the relation between the data and the computer model guarantees the completeness of the data. Recently, this library was reported to have been equipped with anthropometrical scaling [5] capable of partial individualization.

CONCLUSIONS

Much work remains before musculoskeletal models are generally clinically applicable. The amount of work indicates that this must be a worldwide concerted effort, and models for managing this effort must be devised.

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